

QUATERNARY AMMONIUM COMPOUNDS

Cross- Reference

This application claims the benefit of U.S. Provisional Application Serial No.
5 60/421,417 filed on October 25, 2002, under 35 USC 119(e)(i).

Technical Field

The present invention concerns a novel class of quaternary ammonium
compounds, pharmaceutical compositions containing the same, the compounds for use
10 as medicaments, and use of the compounds for the manufacture of specific
medicaments. The present invention also concerns a method of treatment involving
administration of the compounds. The novel compounds are useful as antimuscarinic
agents. In particular, the novel compounds are useful for the treatment of asthma, a
group of breathing disorders termed Chronic Obstructive Pulmonary Disease (COPD),
15 allergic rhinitis, and infectious rhinitis.

Background of the Invention

“Asthma” refers to a chronic lung disease causing bronchoconstriction
(narrowing of the airways) due to inflammation (swelling) and tightening of the
20 muscles around the airways. The inflammation also causes an increase in mucus
production, which causes coughing that may continue for extended periods. Asthma is
generally characterized by recurrent episodes of breathlessness, wheezing, coughing,
and chest tightness, termed exacerbations. The severity of exacerbations can range
from mild to life threatening. The exacerbations can be a result of exposure to e.g.
25 respiratory infections, dust, mold, pollen, cold air, exercise, stress, tobacco smoke, and
air pollutants.

“COPD” refers to Chronic Obstructive Pulmonary Disease, primarily
associated with past and present cigarette smoking. It involves airflow obstruction,
mainly associated with emphysema and chronic bronchitis. Emphysema causes
30 irreversible lung damage by weakening and breaking the air sacs within the lungs.
Chronic Bronchitis is an inflammatory disease, which increases mucus in the airways
and bacterial infections in the bronchial tubes, resulting in obstructed airflow.

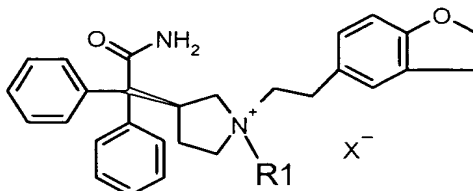
“Allergic rhinitis” refers to acute rhinitis or nasal rhinitis, including hay fever. It
is caused by allergens such as pollen or dust. It may produce sneezing, congestion,
35 runny nose, and itchiness in the nose, throat, eyes, and ears.

“Infectious rhinitis” refers to acute rhinitis or nasal rhinitis of infectious origin.
It is caused by upper respiratory tract infection by infectious rhinoviruses,
coronaviruses, influenza viruses, parainfluenza viruses, respiratory syncytical virus,
adenoviruses, coxsackieviruses, echoviruses, or Group A beta-hemolytic Streptococci

and generically referred to as the common cold. It may produce sneezing, congestion, runny nose, and itchiness in the nose, throat, eyes, and ears.

Summary of the Invention

5 In one aspect, the invention features quaternary ammonium compounds of formula I



and any stereoisomers thereof, wherein

10 R₁ is selected from C₁-C₆ alkyl, -CH₂-(C₁-C₄ alkenyl), and -CH₂-(C₁-C₆ alkynyl), each of which is optionally substituted with a group selected from phenyl, C₁-C₄ alkoxy, and hydroxyl; and

X represents an anion of a pharmaceutically acceptable acid.

Embodiments of this aspect of the invention may include one or more of the following. X is selected from the group consisting of the anions of the following acids:
 15 tartaric, hydrochloric, hydrobromic, hydroiodic, sulfuric, phosphoric, nitric, citric, methanesulfonic, CH₃-(CH₂)_n-COOH where n is 0-4, HOOC-(CH₂)_n-COOH where n is 1-4, HOOC-CH=CH-COOH, and benzoic. X is selected from the group consisting of iodide, bromide, and chloride. The compound is (3S)-3-(2-amino-2-oxo-1,1-diphenylethyl)-1-[2-(2,3-dihydro-1-benzofuran-5-yl)ethyl]-1-methylpyrrolidinium
 20 iodide.

In another aspect the invention features a pharmaceutical composition including a therapeutically effective amount of a quaternary ammonium compound of formula I. The pharmaceutical composition may include a suitable pharmaceutical carrier.

25 In another aspect the present invention also provides a quaternary ammonium compound of formula I for use as a medicament. The present invention also includes using a quaternary ammonium compound of formula I for the manufacture of a medicament for treating asthma, chronic obstructive pulmonary disease (COPD), allergic rhinitis, and infectious rhinitis.

30 In yet another aspect, the invention provides a method of treating asthma, chronic obstructive pulmonary disease (COPD), allergic rhinitis, or infectious rhinitis in a mammal, including man, comprising administering to said mammal, in need of such a treatment, a therapeutically effective amount of a quaternary ammonium compound of formula I.

Advantageously, the quaternary ammonium compounds of formula I

unexpectedly exhibit prolonged efficacy as an antimuscarinic agent when compared to tertiary amine, e.g., non-quaternized, forms of the compounds.

Brief Description of the Drawings

5 Figure 1 is a plot illustrating the average enhanced pause (lung resistance) determined ten minutes after administering, via inhalation, a compound of formula I to Balb/c mice.

 Figure 2 is a plot illustrating the average enhanced pause (lung resistance) determined 36 hours after administering, via inhalation, a compound of formula I to
10 Balb/c mice.

 Figures 3A, 3B, and 3C are plots illustrating the lung resistance of a quaternary ammonium compound of the invention relative to the tertiary amine form of the compound at varying concentrations.

Description of the Invention

15 In describing the preferred embodiment, certain terminology will be utilized for the sake of clarity. Such terminology is intended to encompass the recited embodiments, as well as all technical equivalents that operate in a similar manner for a similar purpose to achieve a similar result. To the extent that any pharmaceutically
20 active compound is disclosed or claimed, it is expressly intended to include all active metabolites produced in vivo, and, is expressly intended to include all enantiomers, isomers or tautomers where the compound is capable of being present in its enantiomeric, isomeric or tautomeric form. All stereoisomers have useful activity. Therefore, the invention includes use of each stereoisomer separately, as well as
25 mixtures thereof.

 The compounds of formula I can be prepared by one skilled in the art. The quaternary ammonium compounds of formula I may be prepared by means, well known to those skilled in the art, for preparing quaternary ammonium compounds from tertiary amines. For instance, the quaternary ammonium compounds may be
30 produced by alkylating the pyrrolidine tertiary nitrogen using the tertiary amines of U.S. Patent No. 5,096,890, the contents of which are hereby incorporated by reference, and other known compounds as starting materials.

 The general term "quaternary ammonium compound" relates to any compound that can be regarded as derived from ammonium hydroxide or an ammonium salt by
35 replacement of all four hydrogen atoms of the NH_4 -ion by organic groups. The specific compounds are for nomenclature reasons (see e.g. Chemical Abstracts) named as "aminium" compounds, but it is possible to use the term "ammonium" in the names. For example, (3R)-3-(2-hydroxy-s-methylphenyl) -N, N-diisopropyl-N-methyl-3-phenylpropanyl aminium bromide can also be named as an ammonium compound:

(3R) - [3- (2-hydroxy-s-methylphenyl)-3-phenylpropyl] diisopropylmethylammonium bromide.

By way of example, a tertiary amine according to U.S. Patent No. 5,096,890, or its salt, is dissolved in a suitable solvent. The tertiary amine is allowed to react with an organic substrate, e.g. an organic halide. The substrate contains a C₁-C₆ alkyl, preferably a C₁-C₃ alkyl, optionally substituted with phenyl, and a leaving group. The identity of the leaving group is not critical, but it is preferred that the leaving group is a halide, such as iodide or bromide. Thus, exemplary substrates include methyl iodide, methyl bromide, ethyl iodide, propyl iodide, benzyl bromide or benzyl iodide. The resulting reaction product is a quaternary ammonium compound, which is readily crystallized in suitable solvents, known to those skilled in the art. The crystals thus produced are quaternary ammonium salts. Their identity is confirmed by standard methods, such as melting point determination, nuclear magnetic resonance (NMR) analysis and mass spectrometry.

The compounds of the invention are preferably administered as quaternary ammonium salts which include counter ions. X represents the anion, e.g., the counter ion, of a pharmaceutically acceptable acid. For instance X may be selected from the following anions: tartrate, chloride, bromide, iodide, sulfate, phosphate(s), nitrate, citrate, methanesulfonate, carboxylates with from two to six carbon atoms, dicarboxylates with from two to six carbon atoms, maleate, fumarate, and benzoate. For other acceptable quaternary ammonium salts, see Int. J. Pharm., 33, 201-217 (1986). Particularly preferred ions are chloride, iodide and bromide, especially bromide and iodide.

The substituent R₁ is selected from the group including C₁-C₆ alkyl, straight or branched, optionally substituted with 1-2 of phenyl or hydroxyl, or both. Thus, R₁ independently represent methyl, ethyl, propyl, isopropyl, butyl, isobutyl, pentyl, isopentyl, hexyl, or isohexyl, optionally substituted with 1-2 of phenyl or hydroxyl, or both. It is particularly preferred that R₁ represents methyl or ethyl, preferably methyl.

The compounds according to the present invention are antimuscarinic agents. "Antimuscarinic agents" refer to muscarinic receptor antagonists. Examples of known antimuscarinic agents include tolterodine, hydroxytolterodine, 2-(diisopropylamino) ethyl-1-phenylcyclopentanecarboxylate, propiverine, oxybutynin, trospium, temiverine, and ipratropium.

Propiverine is 1-methyl-4-piperidyl .alpha., .alpha. -diphenyl-.alpha.-(n-propoxy)acetate and is disclosed in East German Patent 106,643 and in CAS 82-155841s (1975). Oxybutynin is 4-(diethylamino)-2-butylnylalphaphenylcyclohexaneglycolate and is disclosed in UK Patent 940,540. Trospium is 3alpha-hydroxyspiro [1alphaH, 5alphaH-nortropane]pyrrolidinium]chloride benzilate and is disclosed in U.S. Patent No. 3,480,623.

Temiverine is 3S benzeneacetic acid, . alpha. -cyclohexyl- .alpha. -hydroxy-, 4-(diethylamino) -1, 1-dimethyl-2-butynyl ester and is disclosed in U.S. Patent No. 5,036,098. Ipratropium is 8-isopropylnoratropine methobromide and is disclosed in U.S. Patent No. 3,505,337.

5 The compounds of formula I have anti-cholinergic properties and unexpectedly exhibit prolonged activity in the lung. Thus, the compounds of formula I are useful for the treatment of acetylcholine-mediated disorders. In particular, the compounds of are useful for treating asthma, chronic obstructive pulmonary disease (COPD), allergic rhinitis, and infectious rhinitis.

10 The compounds of the present invention are used to treat mammals, including man and horse. It is preferred that the mammal is a human. The compounds according to the invention, in the form of free base or salts with pharmaceutically acceptable acids, or solutions thereof, can be brought into suitable dosage forms, such as compositions for administration through the oral, rectal, transdermal, parenteral, nasal,
15 or pulmonary route in accordance with accepted pharmaceutical procedures. In particular, the compositions may be administered via inhalation or insufflation. Such pharmaceutical compositions according to the invention comprise the compounds according to the invention in association with compatible pharmaceutically acceptable carrier materials, or diluents, as is well known in the art. The carriers may be any inert
20 material, organic or inorganic, suitable for administration, such as: water, gelatin, gum arabicum, lactose, microcrystalline cellulose, starch, sodium starch glycolate, calcium hydrogen phosphate, magnesium stearate, talcum, colloidal silicon dioxide, and the like. Such compositions may also contain other pharmaceutically active agents, and conventional additives such as stabilizers, wetting agents, emulsifiers, flavoring agents,
25 buffers, binders, disintegrants, lubricants, glidants, antiadherents, propellants, and the like. The carrier, e.g., non-active ingredient, can be just (sterile) water with the pH adjusted to where the active pharmaceutical agent is very soluble. It is preferred that the pH be at or near 7. Alternatively and preferably, the non-active carrier agent should be physiological saline with the pH adjusted appropriately.

30 The novel compounds according to the present invention can be administered in any suitable way. The compounds according to the invention can be made up in solid or liquid form, such as tablets, capsules, powders, syrups, elixirs and the like, aerosols, sterile solutions, suspensions or emulsions, and the like. The compounds are advantageously administered via inhalation or insufflation. When the administration
35 form is inhalation or insufflation, the compounds are preferably in the form of either an aerosol or a powder.

 The term "effective amount" refers to a therapeutically effective amount for treating asthma, chronic obstructive pulmonary disease (COPD), allergic rhinitis, or infectious rhinitis. The terms "therapy" and "therapeutically" encompass all kinds of

treatments, including prophylaxis. In particular, "therapeutically effective" means that it is effective for anticholinergic treatment.

For purposes of illustration, dosages are expressed for based on the inhalation of an aerosol solution, such as the product Atrovent Inhalation Aerosol (Boehringer
5 Ingelheim). Adjustments in dosages for administration by other modes of inhaled administration are well known to those skilled in the art.

In general, a therapeutically effective amount of antimuscarinic agent is from about 1 μg to about 1,000 μg , e.g., from about 10 μg to about 1,000 μg or from about 100 μg to about 1000 μg . However, the exact dosage of the specific compound
10 according to the invention will vary depending on its potency, the mode of administration, the age and weight of the patient and the severity of the condition to be treated. The daily dosage may, for example, range from about 0.01 μg to about 10 μg per kg of body weight, administered singly or multiply in doses e.g. from about 1 μg to about 1,000 μg each. The compounds of formula I can be administered from one to
15 four times daily, e.g., once or twice daily.

The dosage form for inhalation can be an aerosol. The minimum amount of an aerosol delivery is about 0.2 ml and the maximum aerosol delivery is about 5 ml. The concentration of the compounds according to the invention may vary as long as the total amount of spray delivered is within the about 0.2 to about 5 ml amount and it
20 delivers a therapeutically effective amount of the compound of formula I. It is well known to those skilled in the art that if the concentration is higher, one gives a smaller dose to deliver the same effective amount.

The dosage form for inhalation can also be via intranasal spray. The minimum amount of an aerosol delivery is about 0.02 ml per nostril and the maximum aerosol
25 delivery is about 0.2 ml per nostril. The concentration of the compounds according to the invention may vary as long as the total amount of spray delivered is within about 0.02 ml per nostril to about 0.2 ml per nostril, e.g., between about 0.05 ml per nostril and about 0.08 ml per nostril, and it delivers a therapeutically effective amount of the compound of formula I.

Of course, the volume of aerosol or intranasal spray for delivering a
30 therapeutically effective amount of the compound of formula I depends upon the concentration of the compound in the aerosol or intranasal spray, e.g., higher concentrations of the compound of formula I require smaller dosage volumes to deliver a therapeutically effective amount and lower concentrations of the compound of
35 formula I require larger dosage volumes to deliver the same therapeutically effective amount.

Aerosols for inhalation of various pharmaceutical agents are well known to those skilled in the art, including many aerosols for treating asthma. Aerosols may be produced with a nebulizer. Typically, the nebulizer is charged with a carrier solution

and the compound of formula I in an amount sufficient to effectively deliver a therapeutically effective amount of the antimuscarinic compound. For instance, depending upon the nebulizer and its operating conditions, the nebulizer may be charged with several hundred mg of antimuscarinic compound in order to deliver about 1 μ g to about 1000 μ g, e.g., from about 10 μ g to about 1000 μ g or from about 50 μ g to about 500 μ g, of the compound of formula I.

The dosage form for inhalation may also be in powder form. Powders for inhalation of various pharmaceutical agents are well known to those skilled in the art, including many powders for treating asthma. When the dosage form is a powder, the compounds according to the invention can be administered in pure form or diluted with an inert carrier. When an inert carrier is used, the compounds according to the invention are compounded such that the total amount of powder delivered delivers an "effective amount" of the compounds according to the invention. The actual concentration of the active compound may vary. If the concentration is lower, then more powder must be delivered; if the concentration is higher, less total material must be delivered to provide an effective amount of the active compound according to the invention.

Pharmaceutically acceptable refers to those properties and/or substances which are acceptable to the patient from a pharmacological/toxicological point of view and to the manufacturing pharmaceutical chemist from a physical/chemical point of view regarding composition, formulation, stability, patient acceptance and bioavailability.

Examples

Without further elaboration, it is believed that one skilled in the art can, using the preceding description, practice the present invention to its fullest extent. The following detailed examples describe how to prepare the various compounds and/or perform the various processes of the invention and are to be construed as merely illustrative, and not limitations of the preceding disclosure in any way whatsoever. Those skilled in the art will promptly recognize appropriate variations from the procedures both as to reactants and as to reaction conditions and techniques.

All temperatures are in degrees Celsius. Ether refers to diethyl ether. Physiological saline refers to a 0.9% aqueous sodium chloride solution. When solvent pairs are used, the ratios of solvents used are volume/volume (v/v). When the solubility of a solid in a solvent is used the ratio of the solid to the solvent is weight/volume (wt/v).

EXAMPLE I: PRODUCTION OF (3S)-3-(2-amino-2-oxo-1,1-diphenylethyl)-1-[2-(2,3-dihydro-1-benzofuran-5-yl)ethyl]-1-methylpyrrolidinium iodide.

(3S)-3-(2-amino-2-oxo-1,1-diphenylethyl)-1-[2-(2,3-dihydro-1-benzofuran-5-yl)ethyl]-1-pyrrolidine (1) is prepared according to the procedures described in U.S. Patent No. 5,096,890. To COMPOUND (1), free base in toluene, is added methyl iodide (1 ml).
5 Acetonitrile (5 ml) is added to the mixture and stirred over night at 20-25°C. The solvent is removed by blowing dry nitrogen. Acetone (1 ml) and hexane (2 ml) are added and the mixture is filtered at 20-25°C to give the title compound. The identity of the compound has been further verified and characterized by NMR analysis, mass spectrometry, and melting point determination.

10
EXAMPLE II: Bronchodilatory effect of inhaled quaternary ammonium salts in Balb/c mice

Female BALB/c mice, weight range 19-22 g, were obtained from Charles River Laboratories (Kingston, NC). They received food and water *ad libitum*. All procedures
15 in these studies were in compliance with the Animal Welfare Act Regulation, 9CFR Parts 1 and 2, Publication (NIH) 85-23, 1985.

Compounds for aerosol administration were prepared in sterile Dulbecco's Phosphate Buffered Saline. Mice were placed in a carousel-style, nose only, exposure chamber and allowed to inhale aerosols for five minutes, using an ICN SPAG-2
20 nebulizer. This nebulizer generates a mean aerosol particle size of 1.3 microns at a rate of approximately 0.25 ml/minute.

Ten minutes and 36 hours later, the mice were moved to whole body plethysmograph chambers. Bronchoconstriction was induced in mice by administration of an 80 mg/ml methacholine (MC) aerosol into the plethysmograph chambers for 5
25 minutes. The mice were allowed to inhale an aerosol containing 80 mg/ml methacholine following inhalation treatment with DPBS vehicle (Dulbecco's Phosphate Buffered Saline), or 80 mg/ml methacholine following inhalation treatment with 1.29 mg/ml of (3S)-3-(2-amino-2-oxo-1,1-diphenylethyl)-1-[2-(2,3-dihydro-1-benzofuran-5-yl)ethyl]-1-methylpyrrolidinium iodide. The average enhanced pause (Penh, lung
30 resistance), corresponding to airflow resistance, was determined and statistically analyzed using Kruskal-Wallis one way ANOVA. In order to determine the baseline, saline aerosol (without methacholine) was also separately administered to the mice.

Referring to Figure 1, Inhalation of the title compound resulted in 100% inhibition of the bronchoconstriction to methacholine when measured 10 minutes after
35 dosing with the title compound. Figure 2 shows a 61% inhibition of the bronchoconstriction to methacholine when measured 36 hours after dosing with the compound of example I.

Referring to Figures 3A-3C, the efficacy of the compound of example I, a quaternary ammonium compound, is compared to its tertiary amine form at varying

concentrations. The compound of example I exhibits extended activity as compared to the tertiary amine form even at higher dosages of the tertiary amine.